Trapping *Lacanobia subjuncta*, *Xestia c-nigrum*, and *Mamestra configurata* (Lepidoptera: Noctuidae) with Acetic Acid and 3-Methyl-1-butanol in Controlled Release Dispensers

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ABSTRACT Both sexes of the noctuid moths *Lacanobia subjuncta* (Grote & Robinson), *Mamestra configurata* Walker (bertha armyworm) and *Xestia c-nigrum* (L.) (spotted cutworm) are attracted to the combination of acetic acid and 3-methyl-1-butanol (isoamyl alcohol). A controlled-release system for use of this attractant in traps was comprised of separate polypropylene vials for each chemical, with the chemical release rate delimited by a hole in the vial lid. When hole sizes for both acetic acid and 3-methyl-1-butanol were varied together, numbers of all three moth species trapped were greatest with vial hole diameters 1.0–3.0 mm. For all three species, captures of moths also were positively correlated with the ratio of acetic acid to 3-methyl-1-butanol vial hole sizes (acetic acid vial hole size was varied, 3-methyl-1-butanol vial hole size was held constant). Captures of these moths were not correlated with the ratio of 3-methyl-1-butanol/acetic acid vial hole sizes (3-methyl-1-butanol vial hole size varied, acetic acid vial hole size was held constant), over the range of hole sizes tested. Captures of *L. subjuncta, M. configurata*, and *X. c-nigrum* in a wet trap were significantly increased by the addition of boric acid to the trap drowning solution (to retard microbial growth and decomposition of specimens). In a comparison of different designs of traps baited with acetic acid and 3-methyl-1-butanol, greatest numbers of all three species were captured in a dry "bucket" trap which moths entered from near the trap top.

KEY WORDS *Lacanobia subjuncta, Mamestra configurata, Xestia c-nigrum*, attractant, trapping, acetic acid

Three noctuid moths that are common pests of agricultural crops in the Pacific Northwest, *Lacanobia subjuncta* (Grote & Robinson), *Mamestra configurata* Walker (bertha armyworm), and *Xestia c-nigrum* (L.) (spotted cutworm) are attracted to the combination of acetic acid and 3-methyl-1-butanol (isoamyl alcohol) (Landolt 2000). These compounds have been isolated from fermented sweet baits, including molasses formulations (Utrio and Eriksson 1977, Landolt 2000). The same species of moths are attracted to fermented molasses (Landolt 1998a). Because these baits and lures attract both sexes of these moths, they may be useful for sampling, monitoring, or controlling these pests in agro-ecosystems.

A previously reported trapping system using acetic acid and 3-methyl-1-butanol as a lure (Landolt 2000) was comprised of a wet trap (Trappit Trap, Agrisense, Fresno, CA) with an entrance in the invaginated trap bottom. Acetic acid was mixed into the drowning solution of the trap and 3-methyl-1-butanol was dispensed from a polyethylene cap mounted inside of the top of the trap. Acetic acid evaporated from the drowning solution and 3-methyl-1-butanol was emitted from the polyethylene cap, probably primarily by diffusion through the cap walls. One limitation of this system is microbial degradation of specimens in the drowning solution that makes identification of trapped moths difficult and may reduce the attractiveness of the lure to moths. Additionally, it is difficult to establish optimum lure parameters, such as attractant release rate and component ratios, using such a trapping system. Quantitative analysis of acetic acid evaporated from water within the trap is problematic and options for provision of a range of release rates of 3-methyl-1-butanol from the cap are limited. Ideally, a controlled release dispenser system is needed to permit the evaluation and selection of optimum chemical release rates and blend ratios and to permit the use of this lure in a dry trap design.

Reported here are the results of field experiments demonstrating the attractiveness of acetic acid and 3-methyl-1-butanol to *L. subjuncta, M. configurata,* and *X. c-nigrum* moths when dispensed from polypropylene vials and the effectiveness of this attractant in both wet and dry traps. Also reported are rates of loss of these compounds from vial dispensers tested under laboratory conditions and changes in numbers of moths captured with selected changes in vial hole sizes to vary chemical release rates. These results provide important improvements in the use of acetic acid and 3-methyl-1-butanol as a lure to attract and trap noctuid moths, compared with methods reported previously (Landolt 2000).

Materials and Methods

General. Polypropylene vials (Nalgene 2006–9025, Fisher, Pittsburgh, PA) were used as controlled release dispensers in most experiments, with the release rate governed by the size of hole drilled through the vial lid. Eight-milliliter vials were used in trapping experiments, each loaded with 5 ml of a chemical. Two cotton balls were firmly placed within the bottom of each vial to hold the liquid glacial acetic acid (Baker Chemical, Phillipsburg, NJ) or 3-methyl-1-butanol (Aldrich, Milwaukee, WI) and prevent spillage if vials were tipped. Release of acetic acid and of 3-methyl-1-butanol from these vials was quantified for a range of lid hole diameters (0, 0.5, 1.0, 1.6, 3.0, and 6.4 mm) in the laboratory using a gravimetric method. That is, vials were weighed periodically to determine rates of weight loss. Weight loss was assumed to be caused by evaporation of the chemical from the vial. For each chemical and for each hole diameter, four 8-ml vials were loaded with 5 ml chemical, held in a laboratory fume hood (2°C), and were then weighed at intervals of 1–5 d for 30 d to monitor weight loss. Mean weight loss amounts were subjected to a regression analysis (DataMost 1995) to determine if there was a significant relationship between lure age and rate of loss of active ingredient.

Five field experiments were conducted to improve a trapping system for use in attracting and capturing *L. subjuncta, M. configurata,* and *X. c-nigrum.* These five experiments were as follows: (1) an assessment of any effect of boric acid (added to the trap drowning solution to retard decay) on captures of moths attracted to acetic acid and 3-methyl-1-butanol, (2) a comparison of captures of moths in traps with varying vial hole diameters for both acetic acid and 3-methyl-1-butanol, (3) a comparison of captures of moths in traps with varying vial hole diameters for acetic acid and holding constant the vial hole diameter for 3-methyl-1-butanol, (4) a comparison of captures of moths in traps with varying vial hole diameters for 3-methyl-1-butanol and holding constant the vial hole diameter for acetic acid, and (5) a comparison of different trap designs. Data were obtained on numbers of males and females of each of the three moth species captured in traps in these experiments. Because numbers of males and females trapped were similar among treatments throughout the experiments, these data were combined for statistical analyses and for presentation in tables and figures.

Effects of Boric Acid. This experiment compared baited traps with or without boric acid (#A7710, Fisher) in the drowning solution. Boric acid prevents microbial growth and can be added to the drowning solution to minimize the deterioration of specimens. Borax formulations have been used in similar wet trap designs for tephritid fruit flies to retard decomposition (Lopez and Hernandez 1967). This experiment was conducted to determine if the addition of boric acid to the drowning solution of Trappit traps affects captures of moths. Boric acid (1% by weight) was added to the drowning solution of treatment traps. All traps contained 200 ml of the drowning solution, a combination of 125 μl of dishwashing detergent per liter of water. All traps, treatment and control, were baited with acetic acid and 3-methyl-1-butanol formulated as reported previously (Landolt 2000). Acetic acid was added to the drowning solution (0.25% by volume) and 1 ml of 3-methyl-1-butanol was loaded into a 2-ml polyethylene cap (No. 60975 d-3, Kimball Glass, Vineland, NJ) mounted in the top of the inside of the trap. Control and treatment traps were paired, and 10 pairs of traps were set up, 25 m apart, in a commercial apple orchard in the Parker Heights area of Yakima County, WA. Traps were checked two times per week and were moved one position in a block each time they were checked, and trap drowning solution was replaced weekly. The experiment was begun 17 April 1999 and ended 24 May 1999. Data were combined and analyzed by Student *t*-test as weekly trap catch totals (DataMost 1995).

Comparison of Attractant Release Rates. For this experiment, acetic acid and 3-methyl-1-butanol were loaded into separate polypropylene vials. The two vials were then wired together and mounted inside the tops of traps. Six hole diameters were tested (0, 0.5, 1.0. 1.6, 3.0, and 6.4 mm) to provide an assessment of the effects of increasing release rates on captures of moths. Within each treatment, vials for both acetic acid and 3-methyl-1-butanol had the same hole size. A randomized complete block design was used, with all five treatments represented within each of 10 blocks. Blocks of traps were placed within rows of apple trees in a commercial apple orchard near Prosser, Benton County, WA, on 15 April 1999 and were maintained until 24 June, then again from 11 August to 25 August 1999. Traps were 20 m apart and blocks were in rows >30 m apart. Traps were checked three times per week and moved one position in a block each time they were checked. Drowning solution was changed weekly and lures were replaced every 2 wk.

Trap catch data for each species were subjected to analysis of variance (ANOVA) and means were separated by Tukey test at a significance level of $P < 0.05$ (DataMost 1995).

Varying of Acetic Acid Vial Hole Sizes. Acetic acid and 3-methyl-1-butanol were loaded into separate polypropylene vials. All vials containing 3-methyl-1-butanol had holes of 3.0 mm diameter in the lids, whereas the holes in acetic acid vials were varied as treatments (diameters of 0, 0.5, 1.0, 1.6, and 3.0 mm). The hole size of 3.0 mm diameter for the 3-methyl-1-butanol vial was selected based on the results of the above test comparing chemical release rates. Traps contained 200 ml of the drowning solution, which was replaced weekly. A randomized complete block design was used, with all five treatments represented within each block. Five blocks of traps were placed within rows of apple trees in a commercial apple orchard near Prosser, Benton County, WA, on 17 August 1999 and were maintained until 3 September. An additional five blocks of traps were placed in a commercial apple orchard near Royal City, Grant County, WA, on 25 August and were maintained until 3 September. Traps within a block were placed 20 m apart and blocks were at least 30 m apart. Traps were checked twice per week and were moved one position within a block each time they were checked.

For each of the three moth species, mean trap catch data were subjected to a linear regression analysis (DataMost1995) to determine if their was a significant correlation between the diameter of the hole in the acetic acid vial (controlling release rate) and the numbers of moths captured in traps baited with acetic acid and 3-methyl-1-butanol.

Varying of 3-Methyl-1-butanol Vial Hole Sizes. Acetic acid and 3-methyl-1-butanol were loaded into separate 8-ml vials. All vials containing acetic acid had holes of 3.0 mm diameter in the lids, whereas the holes in 3-methyl-1-butanol vials were varied as treatments (0, 0.5, 1.0, 1.6, 3.0, and 6.4 mm diameter). The hole size of 3.0 mm diameter for the acetic acid vial was selected based on the results of the above test comparing chemical release rates. Traps contained 200 ml of the drowning solution, which was replaced weekly. A randomized complete block design was used, with all six treatments represented within each block. Five blocks of traps were placed within rows of apple trees in a commercial apple orchard near Prosser, Benton County, WA, on 1 May 2000 and were maintained until 8 June 2000. Traps within a block were placed 20 m apart and blocks were at least 30 m apart. Traps were checked twice per week and were moved one position within a block each time they were checked. Vials were replaced every 2 wk.

For each of the three moth species, mean trap catch means were subjected to a linear regression analysis (DataMost1995) to determine if there was a significant correlation between the diameter of the hole in the vial containing 3-methyl-1-butanol (controlling release rate) and the numbers of moths captured in traps baited with acetic acid and 3-methyl-1-butanol. In addition, means were separated using Tukey test following a significant F value in an ANOVA (DataMost 1995).

Comparison of Trap Design. Five trap designs were compared for their effectiveness in capturing moths attracted to acetic acid and 3-methyl-1-butanol. These five traps were the Trappit trap, the Universal Moth trap or Unitrap (Agrisense, Fresno, CA), the glass McPhail trap (Newell 1936), the Multipher trap (BioControle, Ste Foy, Quebec), and a horizontal trap consisting of a yellow plastic cylinder 9 cm in diameter and 25 cm long, open on both ends and with screen cones inserted into the two cylinder openings. Universal moth traps comprised an opaque white bucket topped by a yellow cone and a dark green top. All traps were baited with two polypropylene vials; one loaded with acetic acid and with a hole 3.0 mm in diameter and another loaded with 3-methyl-1-butanol and with a hole 3.0 mm in diameter. Multipher traps, horizontal traps, and Universal Moth traps each contained a piece of Vaportape (25 by 25 mm) (Hercon Environmental, Emigsville, PA) to kill captured moths. The Trappit and McPhail traps contained the standard drowning solution. A randomized complete block design was used, with all five treatments included in each block. Five blocks of traps were placed in apple trees in a commercial apple orchard 7 September 1999 and were maintained until 21 September 1999. Traps within a block were placed 20 m apart and blocks were at least 30 m apart. Traps were checked two times per week and drowning solutions were replaced weekly. Traps were moved one position each time they were checked. For each of the three moth species, trap catch data were subjected to an ANOVA and means were compared by Tukey test, following a significant F (DataMost 1995).

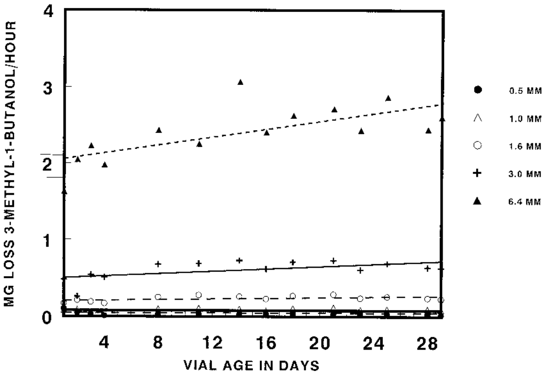

Fig. 1. Mean weight losses of 8-ml polypropylene vials loaded with 5 ml of acetic acid and with varying sizes (up to 6. 4 mm) of holes in the vial lids.

Results

Dispenser Release Rates. Acetic acid losses from 8-ml polypropylene vials were 0 μg/h for closed vials, 218 μg/h for vials with 0.5 mm holes, 509 μg/h for vials with 1.0 mm holes, 1,081 μg/h for vials with 1.6 mm holes, 3,321 μg/h for vials with 3.0 mm holes, and 8,239 μg/h for vials with 6.4 mm holes (Y intercepts for best fit line equations for vials with hole sizes of 0, 0.5, 1.0, 1.6, 3.0 and 6.4 mm, respectively, Fig. 1). Throughout the 28-d period, rates of loss were similar, with no significant decrease in rate of weight loss from vials loaded with acetic acid. For hole diameters of 0.5 (r^2 = 0.18, df = 10, P = 0.92), 1.0 (r^2 = 0.25, df = 10, P = 0.22), 1.6 (r^2 = 0.0.34, df = 10, P = 0.24), 3.0 (r^2 = 0.33, df = 10, P = 0.62), and 6.4 mm (r^2 = 0.47, df = 10, P = 0.37), there was no significant relationship between lure age and rate of weight loss. Rate of loss of acetic acid from closed vials was not detectable over the 28-d period, with a detection limit of 10 μg/h.

3-Methyl-1-butanol rates of loss from 8-ml polypropylene vials were 0 μg/h for closed vials, 50 μg/h for vials with 0.5-mm holes, 80 μg/h for vials with 1.0-mm holes, 180 μg/h for vials with 1.6-mm holes, 560 μg/h for vials with 3.0-mm holes, and 2,004 μg/h for vials with 6.4-mm holes (Y intercepts for best fit line equations for vials with hole sizes of 0, 0.5, 1.0, 1.6, 3.0 and 6.4 mm respectively, Fig. 2). Over the 30-d period, there was no significant decrease in the rate of weight loss in vials loaded with 3-methyl-1-butanol for all hole

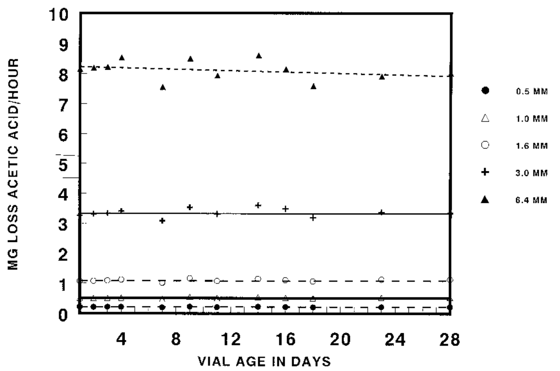

Fig. 2. Mean weight losses of 8 -ml polypropylene vials loaded with 5 ml of 3-methyl-1-butanol and with varying sizes (up to 6. 4 mm) of holes in the vial lids.

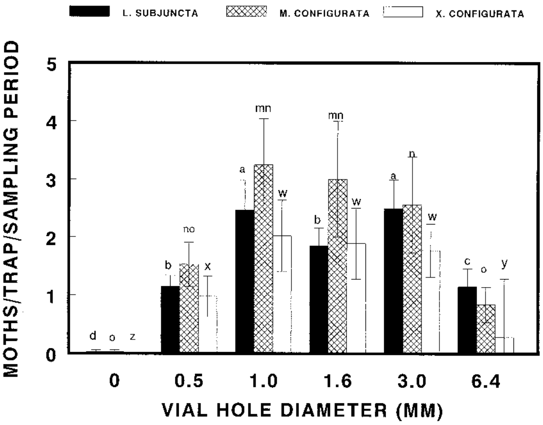

Fig. 3. Mean (±SE) numbers of moths captured every 2–3 d in Trappit traps baited with acetic acid and 3-methyl-1-butanol released in different amounts from vials. Treatment release rates were altered with diameter of holes in vials for acetic acid and vials for 3-methyl-1-butanol. Within each moth species, bars capped with the same letter are not significantly different by Tukey test at $P > 0.05$. a–d, *L. subjuncta;* m–o for *M. configurata;* and x–z for *X. c-nigrum.*

diameters tested. However, there was a slight positive regression of weight loss with vial age for the 1.6-, 3.0-, and 6.4-mm-diameter vial holes (for 0.5-mm diameter holes, $r^2 = 0.18$, df = 1,10, $P = 0.13$; for 1.0-mm diameter holes, $r^2 = 0.25$, df = 1,10, $P = 0.07$; for 1.6-mm diameter holes, $r^2 = 0.34$, df = 1,10, $P = 0.03$; for 3.0-mm diameter holes, $r^2 = 0.33$, df = 1,10, $P = 0.03$, and for 6.4-mm diameter holes, $r^2 = 0.47$, df = 1,10, $P = 0.007$). Rate of loss of 3-methyl-1-butanol from closed vials was <10 μg/h over the 30-d period.

Effects of Boric Acid. Numbers of *L. subjuncta* moths captured in traps baited with 0.25% acetic acid in the drowning solution and 1 ml of 3-methyl-1-butanol in a polyethylene cap were significantly increased when 1% boric acid was added to the drowning solution ($t = 2.00$, df = 58, $P < 0.03$). In total, 87 (37 male and 50 female) *L. subjuncta* moths were captured, with 51 *L. subjuncta* moths captured in traps containing boric acid (1.5 + 0.3 moths per trap per week) and 36 in traps without boric acid (0.9 moths per trap per week). Numbers of *M. configurata* moths and *X. c-nigrum* moths were too low in this test for a statistical comparison.

Comparison of Chemical Release Rates. Numbers of moths trapped generally increased when vial hole sizes were increased from 0 to 1.0 mm, and then generally decreased with vial hole diameters increased from 3.0 to 6.4 mm (Fig. 3). Numbers of *L. subjuncta* captured in traps baited with acetic acid and 3-methyl-1-butanol dispensed from vials with identical hole diameters of 0.5, 1.0, 1.6, 3.0, and 6.4 mm (Fig. 3) were all greater than in traps with vials with hole sizes of 0. Greatest numbers of *L. subjuncta* were captured in traps baited with vial dispensers having hole diameters of 1.0 and 3.0 mm. Totals of 170 male and 159 female *L. subjuncta* were captured. Numbers of *M. configurata* captured in traps baited vials with hole sizes of 1.0, 1.6, and 3.0 mm in diameter (Fig. 3) were significantly greater than in traps with hole sizes of 0. Greatest numbers of *M. configurata* were captured in traps baited with vial dispensers having 1.0-, 1.6-, and 3.0-mm hole diameters. Totals of 208 male and 175 female *M. configurata* were captured. Numbers of *X. c-nigrum* moths captured in traps baited with vials having holes that were 0.5, 1.0, 1.6, 3.0, and 6.4 mm diameter were signficantly greater than numbers in traps baited with closed vials (Fig. 3). Greatest numbers of *X. c-nigrum* were in traps baited with vial dispensers with hole diameters of 1.0, 1.6, and 3.0 mm. Totals of 165 male and 154 female *X. c-nigrum* were captured.

Comparison of Ratios of Acetic Acid to 3-Methyl-1-butanol. Numbers of *L. subjuncta* captured in traps baited with acetic acid and 3-methyl-1-butanol were positively correlated with the hole size for the acetic acid vial ($r^2 = 0.12$, $F = 19.52$, df = 149, $P = 1.9 \times 10^{(5)}$) (Fig. 4). In this experiment, all treatments included a 3-methyl-1-butanol vial with a 3.0-mm diameter hole. Totals of 70 male and 19 female *L. subjuncta* were captured. In this same experiment, numbers of *M. configurata* captured in traps baited with acetic acid and 3-methyl-1-butanol were also positively correlated with vial hole size for the acetic acid vial ($r^2 = 0.11$, $F = 23.3$, df = 199, $P = 2.7 \times 10^{(6)}$) (Fig. 4). Totals of 183 male and 147 female *M. configurata* were captured. Numbers of *X. c-nigrum* captured in traps baited with acetic acid and 3-methyl-1-butanol were positively correlated with the hole size for the acetic acid vial ($r^2 = 0.11$, $F = 18.0$, df = 144, $P = 4.0 \times 10^{(5)}$) (Fig. 4). Totals of 36 male and 59 female *X. c-nigrum* were captured.

Comparison of Ratios of 3-Methyl-1-butanol to Acetic Acid. Numbers of *L. subjuncta* captured in traps baited with acetic acid and 3-methyl-1-butanol were not positively correlated with the hole size for the 3-methyl-1-butanol vial when means of data for hole diameters of 0 up to 3.0 mm diameter were analyzed ($r^2 = 0.00$, $F = 0.00$, df = 5, $P = 0.99$) (Fig. 5). Numbers of *L. subjuncta* captured were significantly higher with

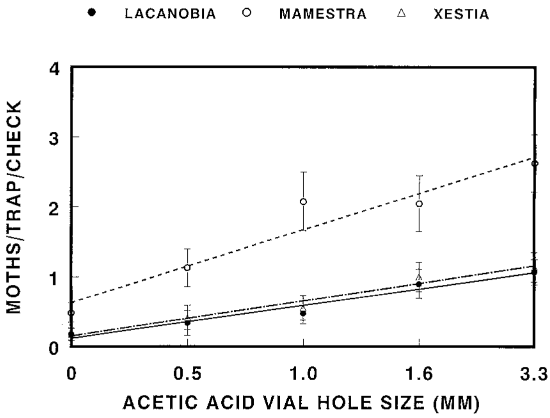

Fig. 4. Mean (±SE) numbers of *L. subjuncta*, *X. C-nigrum*, and *M. configurata* moths captured in Trappit traps baited with acetic acid and 3-methyl-1-butanol released at different ratios from vials. All vials with 3-methyl-1-butanol had holes 3.0 mm in diameter, whereas vials with acetic acid possessed holes ranging in size from 0 to 6.4 mm in diameter.

3-methyl-1-butanol vial hole sizes of 0.5, 1.0, 1.6, 3.0 mm, and 6.4 mm compared with traps with 3-methyl-1-butanol in closed vials (hole diameter of 0 mm) (Fig. 5). In this experiment, all treatments included a vial containing 5 ml of acetic acid that had a hole 3.0 mm in diameter in the lid. Totals of 110 female and 79 male *L. subjuncta* were captured in this experiment. In this same experiment, numbers of *M. configurata* captured in traps baited with acetic acid and 3-methyl-1-butanol were also not positively correlated with vial diameter size for the 3-methyl-1-butanol vial, when means for data from the 0–3.0 mm hole diameters were analyzed ($r^2 = 0.09$, $F = 1.51$, df = 5, $P = 29$) (Fig. 5). Numbers of *M. configurata* captured were significantly greater in traps with 3-methyl-1-butanol vials with hole sizes of 0.5, 1.0, and 3.0 mm, compared with traps with closed vials. Totals of 183 female and 194 male *M. configurata* were captured in this experiment. Numbers of *X. c-nigrum* captured in traps baited with acetic acid and 3-methyl-1-butanol also were not positively correlated with the hole size for the 3-methyl-1-butanol vial, when means for data from hole sizes of 0–3.0 mm were analyzed ($r^2 = 0.09$, $F = 0.37$, df = 5, $P = 0.57$). Captures of *X. c-nigrum* moths were significantly greater in traps baited with 3-methyl-1-butanol in vials with hole diameters of 0.5, 1.0, 1.6, and 3.0 mm, compared with no hole (Fig. 5). In total, 359 female and 267 male *X. c-nigrum* moths were captured in this experiment.

Comparison of Trap Design. In the direct comparison of different traps baited with acetic acid and 3-methyl-1-butanol, significantly more moths of all three species were captured in Universal Moth traps (UniTraps), than in all others (Table 1; Fig. 6). Also, for *M. configurata* and *X. c-nigrum*, numbers of moths captured with the Multipher trap were significantly greater than for the horizontal trap, but were not significantly greater than for the Trappit or McPhail traps. Totals of 71 male and 16 female *L. subjuncta*, 100 male and 83 female *M. configurata*, and 245 male and 129 female *X. c-nigrum* were captured in this test.

Table 1. Mean (±SE) numbers of moths trapped every 3–4 d with lures of acetic acid and 3-methyl-1-butanol in different types of traps

Trap Type	*Lacanobia*	*Mamestra*	*Xestia*
McPhail	0.50 ± 0.13a	1.00 ± 0.28ab	1.75 ± 0.27ab
Trappit	0.49 ± 0.17a	1.30 ± 0.25ab	1.80 ± 0.50ab
Unitrap	1.71 ± 0.36b	4.30 ± 1.18c	10.05 ± 2.17c
Multipher	0.79 ± 0.26a	2.35 ± 1.67b	3.65 ± 0.99b
Horizontal	0.17 ± 0.10a	0.05 ± 0.05a	1.40 ± 0.51a

Means within a column followed by the same letter are not significantly different by Tukey test at $P < 0.05$.

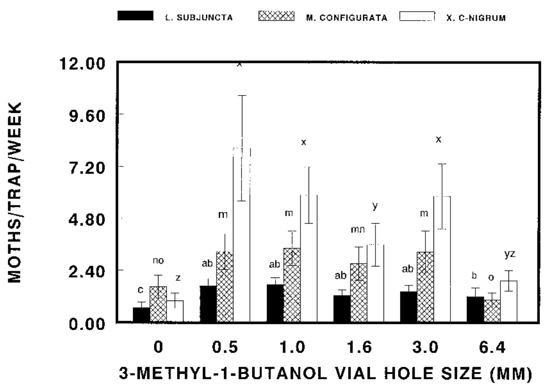

Fig. 5. Mean (±SE) numbers of *L. subjuncta*, *M. configurata*, and *X. c-nigrum* moths captured in Trappit traps baited with acetic acid and 3-methyl-1-butanol released at different ratios from polypropylene vials. All vials with acetic acid had holes 3.0 mm in diameter, whereas vials with 3-methyl-1-butanol had holes ranging in size from 0 to 6.4 mm. For each moth species, bars capped with the same letter are not significantly different by Tukey test at $P > 0.05$. a–c, *L. subjuncta;* m–o, *M. configurata;* x–z, *X. c-nigrum.*

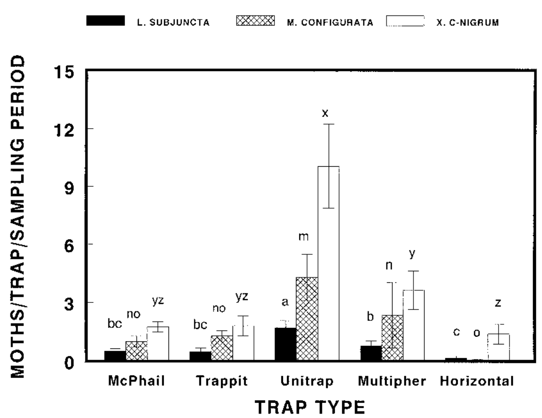

Fig. 6. Mean (±SE) numbers of *L. subjuncta*, *M. configurata*, and *X. c-nigrum* moths captured in different traps baited with acetic acid and 3-methyl-1-butanol. For each moth species, bars capped with the same letter are not significantly different by Tukey's test at *P* 0.05; letters a to c for *L. subjuncta*, m to o for *M. configurata*, and x to z for *X. c-nigrum.*

Discussion

These results demonstrate the use of a method of evaporating acetic acid and 3-methyl-1-butanol from a controlled release dispenser and of altering the rate and ratio of evaporation of these chemicals for experimental purposes. The previously used method of presenting these chemicals involved mixing acetic acid into the drowning solution and dispensing 3-methyl-1-butanol from a polyethylene cap (Landolt 2000). This new system has clear advantages over the previous method. Quantifying the release of chemicals from the polypropylene vials can be done by weighing vials at time intervals if the release rate is high enough to be detectable. This could not be done with acetic acid in dilute aqueous solutions. A broad range of release rates that encompasses the optimum release rates for these feeding attractants is provided. In addition, the use of vials and the delimitation of chemical release to the vapor escaping from small holes provides a long-term near zero-order controlled release system for both chemicals.

This dispenser method also permits the baiting of dry traps with acetic acid and 3-methyl-1-butanol for capturing *L. subjuncta, M. configurata* and *X. c-nigrum* moths for purposes of monitoring, detection, or sampling. When using a wet trap in which moths are killed in a drowning solution, insects captured soon begin to decompose, making it difficult to identify moths captured and also adding odors to the attractant of the trap which may reduce the attractiveness of the system to the target insects. This may explain why the addition of 1% boric acid to the drowning solution increased captures of noctuid moths; it may have inhibited microbial growth in the drowning solution and reduced the production of volatile chemicals agonistic to the attractiveness of acetic acid and 3-methyl-1-butanol. Alternatively, boric acid in the drowning solution could alter the release of acetic acid from that same solution. Regardless, the use of a dry trap permits the rapid knockdown of captured insects with an insecticide, providing more readily identifiable specimens, and also minimizes production of odors from decomposing specimens.

These results provide for the improvement of attractiveness of the odor blend comprised of acetic acid and 3-methyl-1-butanol by demonstrating differences in attractiveness of various chemical release rates (vial hole diameters) to *L. subjuncta, M. configurata,* and *X. c-nigrum* moths. These vials in the laboratory lost 0.22–8.24 mg/h of acetic acid (holes 0.5–6.4 mm in diameter) and 0.05–2.04 mg//h of 3-methyl-1-butanol. Release rates in the field would vary from these measurements, depending on environmental conditions. The ratio of acetic acid to 3-methyl-1-butanol was initially of concern because of inhibitory effects observed from high concentrations of acetic acid in the drowning solution in previous studies (Landolt 2000). It was thought that a lower release rate relative to that of 3-methyl-1-butanol may be optimal. This, however, was not the case. It appears from results of these tests that best results were obtained with acetic acid released from vials with holes 3.0 mm in diameter ($\approx$3 mg/h in the laboratory) and with 3-methyl-1-butanol released from vials with hole diameters of 0.5–3.0 mm (0.05–0.5 mg/h in the laboratory). Additional improvements in moth responses to this attractant may be found by testing a lower range of 3-methyl-1-butanol release rates.

Results of the comparison of trap designs indicated an increase of three to five times in capture of attracted moths with the Universal moth trap (Unitrap) compared with the Trappit trap (also referred to as the dome trap) that had been used in previous studies with acetic acid and 3-methyl-1-butanol (Landolt 2000). The reasons for these differences in capture rates with different traps are not known and will require additional experimentation. However, design differences that may have a strong effect on moth captures should be evaluated further. One trap design variable is the direction from which moths enter the trap—from below for the McPhail and Trappit, from above for the Universal Moth and the Multipher trap, and from the side in the horizontal trap. Other variables are the color and reflectivity of the trap that may affect short-range orientation as well as the likelihood of escape of attracted moths. The McPhail trap is clear glass, whereas the Trappit trap is opaque yellow on the bottom and clear plastic above; the Unitrap is white below and dark green on the top with a yellow cone in between; the horizontal trap is translucent yellow; and the Multipher trap is white below and dark green above. Other variables to consider are the position and placement of the attractant dispensers within the trap and diameter of trap entrance holes.

The information given here provides an improved attractant, dispenser, and trap for use in monitoring these and other pest species of Noctuidae. Because the system includes an attractant for both males and females, it should provide information which otherwise cannot be obtained with sex pheromone and sex attractant lures, which are available for all three of these moth species (Chisholm et al. 1975, Steck et al. 1982, Landolt and Smithhisler 1998). For example, where mating disruption is attempted and monitoring with sex pheromone lures is not possible, such a lure may provide a means of sampling females to assess mating status.

Adult moths feed at a variety of sugar sources such as fruits, saps, flowers, and plant surfaces (Norris 1935). Chemical feeding attractants identified for moths are based largely upon adult moth feeding on floral nectars or at fermented sweet baits. For example, the cabbage looper, *Trichoplusia ni* (Hübner), is attracted to chemicals emitted from attractive flowers (Cantelo and Jacobson 1979, Haynes et al. 1991, Heath et al. 1992). Also, a number of species of moths are attracted to fermented sugar solutions and other sweet materials (Frost 1926, Eyer 1931, Ditman and Cory 1933, Landolt 1995, Yamazaki 1998). Odorants from such sources have been tested for attractiveness to moths, with some limited success in developing useful lures for pest insects (Dethier 1947, Utrio and Eriksson 1977). The combination of acetic acid and 3-methyl-1-butanol is considered to be a feeding attractant because the same moths (*L. subjuncta, M. configurata,* and *X. c-nigrum*) are attracted to fermenting molasses solutions (Landolt 1998a) and because acetic acid and 3-methyl-1-butanol were isolated from volatiles released from fermenting solutions of molasses and jaggery (Landolt 2000). 3-Methyl-1-butanol was also isolated and identified as an odorant from some bacteria (DeMilo et al. 1996, Lee et al. 1997) and acetic acid and 3-methyl-1-butanol were among a set of volatile chemicals found in a fermented sweet bait comprising a solution of sucrose, fructose, glucose, and brown sugar and then tested as moth attractants by Utrio and Eriksson (1977).

Fermented solutions of sugars, such as molasses or jaggery, are attractive to a large number of species of insects of various taxonomic groups. One difficulty in using such materials for sampling or detection is the numbers of nontarget insects attracted and trapped. There was concern that similar problems would be encountered with the use of chemical attractants isolated and identified from these sources. There appears, however, to be some degree of specialization in insect responses to these feeding attractant chemicals. Acetic acid and isobutanol together are attractive primarily to social wasps (Landolt 1998b, Landolt et al. 1999), whereas acetic acid and 3-methyl-1-butanol together are attractive primarily to noctuid moths (Landolt 2000, Landolt and Hammond 2001, herein) and acetic acid and ethanol together are attractive primarily to many Diptera (Dethier 1947). The natural sources of these attractants are not known bccause molasses is a artificial product. In the case of these species of Noctuidae, we do not have detailed information on what sources of food they access in nature. A general assessment of the types of materials that adult moths feed on in nature was provided by Norris (1935).

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